Spatial and Temporal Variation in Natural Enemy Assemblages on Maryland Native Plant Species

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ABSTRACT Habitat manipulation is a branch of conservation biological control in which vegetation complexity and diversity are increased in managed landscapes to provide food and other resources for arthropod natural enemies. This is often achieved by maintaining noncrop plant material such as flowering strips and beetle banks that provide natural enemies with nectar and pollen, alternative prey, shelter from disturbance, and overwintering sites. In most cases, plant material used in habitat manipulation programs is not native to the area in which it is planted. Using native plant species in conservation biological control could serve a dual function of suppressing pest arthropod outbreaks and promoting other valuable ecosystem services associated with native plant communities. We evaluated 10 plant species native to Maryland for their attractiveness to foliar and ground-dwelling natural enemies. Plants that showed particular promise were *Monarda punctata*, *Pycnanthemum tenuifolium*, and *Eupatorium hyssopifolium*, which generally harbored the greatest abundance of foliar predators and parasitoids, although abundance varied over time. Among ground-dwelling natural enemies, total predator and parasitoid abundance differed between plant species, but carabid and spider abundance did not. Matching certain plant species and their allied natural enemies with specific pest complexes may be enhanced by identifying the composition of natural enemy assemblages at different times of year and in both foliar and ground habitat strata.

KEY WORDS conservation biological control, habitat manipulation, insectary plants, beetle banks, native plants

Conservation biological control involves restoring natural predator–prey linkages in managed landscapes by conserving natural enemies and their associated resources. Habitat manipulation is a branch of conservation biological control in which vegetation complexity and diversity is increased to provide food and other resources to arthropod natural enemies (Gurr et al. 2000, Landis et al. 2000). This is often achieved by maintaining noncrop plant material such as flowering strips and beetle banks within or around pest prone fields or landscapes. Making these habitats more hospitable to natural enemies may help reduce pest arthropod outbreaks and pesticide applications.

Flowering plants offer natural enemies pollen and nectar, alternative prey, favorable microclimates, and refuge from disturbance (Landis et al. 2000). Alternative food resources and complex habitats can increase natural enemy longevity and fecundity (Idris and Grafius 1995, Tylianakis et al. 2004, Irvin et al. 2006) and reduce intraguild predation (Wagner and Wise 1997, Cottrell and Yeargan 1998, Finke and Denno 2002), all of which may contribute to greater natural enemy abundance in complex habitats (Langellotto and Denno 2004, Shrewsbury and Raupp 2006). The addition of flowering insectary strips has successfully increased natural enemy abundance in agricultural (Hickman and Wratten 1996, Patt et al. 1997, Chaney 1998) and ornamental systems (Frank and Shrewsbury 2004, Shrewsbury et al. 2004, Rebek et al. 2005). Moreover, flowering insectary strips have resulted in higher predation or parasitism rates and lower pest populations in some systems (Patt et al. 1997, Chaney 1998, Frank and Shrewsbury 2004, Shrewsbury et al. 2004, Tylianakis et al. 2004, Ellis et al. 2005).

Increasing vegetation complexity, even in the absence of floral resources, is a good predictor of natural enemy abundance (Langellotto and Denno 2004, Shrewsbury and Raupp 2006) and can result in lower pest populations (Shrewsbury and Raupp 2000, 2006). Beetle banks comprised of bunch grass, such as *Dactylis glomerata*, provide overwintering habitat and refuge from routine farm disturbances for carabid beetles, staphylinid beetles, and spiders (Thomas et al. 1991). Frank and Shrewsbury (2004) combined the concepts of beetle banks and flowering insectary strips to create conservation strips next to golf course fairways. Conservation strips increased the abundance of foliar and ground-dwelling natural enemies such as carabids, staphylinids, and spiders. In addition, predation of black cutworms, *Agrotis ipsilon* Hufnagel

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(Lepidoptera: Noctuidae), was greater on fairways where conservation strips were present compared with where they were absent (Frank and Shrewsbury 2004).

Selection of plant species that attract and retain large populations of natural enemies is an important first step in habitat manipulation. To identify plant species that may be useful in conservation biological control, research is needed that compares natural enemies harbored by individual plant species (Thomas et al. 1991, Jervis et al. 1993, Al-Doghairi and Cranshaw 1999, Colley and Luna 2000, Wäckers 2004, Fiedler and Landis 2007). The most common flower species that have been evaluated and recommended include sweet alyssum, *Lobularia maritima* L. (Brassicaceae), buckwheat, *Fagopyrum esculentum* Moench (Polygonaceae), phacelia, *Phacelia tanacetifolia* Benth (Hydrophyllaceae), and umbelliferous herbs such as coriander, *Coriandrum sativa* L. (Apiaceae), fennel, *Foeniculum vulgare* Miller (Apiaceae), and dill, *Anethum graveolens* L. (Apiaceae). These species are also the most commonly implemented in field research (White et al. 1995, Hickman and Wratten 1996, Stephens et al. 1998, Berndt et al. 2002, Frank and Shrewsbury 2004, Shrewsbury et al. 2004, Tylianakis et al. 2004, Ellis et al. 2005, Irvin et al. 2006). None of the above species are native to North America, except *P. tanacetifolia,* which is native to some western states (USDA–NRCS 2008). However, *P. tanacetifolia* is not native to England and New Zealand, where it is often used in habitat manipulation. Likewise, orchard grass, *Dactylis glomerata* L. (Poaceae), previously determined to attract ground-dwelling predators in European beetle banks, is considered an invasive plant in the United States (USDA–NRCS 2008).

Although exotic plant species have been recommended and used with success, native plant species could enhance conservation biological control and provide other benefits to managed ecosystems. Native plants are adapted to local environmental conditions, which could increase their survival and reduce associated maintenance costs. Likewise, native natural enemy populations have evolutionary associations with local plants and herbivores (Tallamy 2004). Thus, reducing the proportion of native plants in a landscape can reduce overall insect diversity (Samways et al. 1996), which has the potential to interrupt valuable ecosystem services such as biological control (Tscharntke et al. 2005). Moreover, exotic plants have the potential to become invasive, which degrades local plant diversity and negatively affects agricultural practices (Vitousek et al. 1997, DiTomaso 2000, Pimentel et al. 2000). For these reasons, using native plants in conservation biological control provides an opportunity to benefit native plant communities and increase the efficacy of sustainable pest management.

Research on plant species that attract natural enemies—including one study on native plant species—has focused on natural enemies present at the time a plant is flowering (Colley and Luna 2000, Fiedler and Landis 2007). However, plant biomass or architecture and alternative prey can attract natural enemies even when flowers are not in bloom (Langellotto and Denno 2004, Rebek et al. 2005, Shrewsbury and Raupp 2006). Moreover, land that is set aside for insectary plantings is out of production for the entire season. Therefore, plant species that attract natural enemies throughout their phenological cycle will increase the benefit of these plantings. In addition, previous studies have neglected the potential of flowering plants to attract ground-dwelling natural enemies just as beetle bank research has neglected the potential for grasses to attract foliar predators and parasitoids (Thomas et al. 1991, Al-Doghairi and Cranshaw 1999, Colley and Luna 2000, Wäckers 2004, Fiedler and Landis 2007). Ideally, land dedicated to beneficial plantings would attract and retain a diverse complex of ground- and foliar-dwelling natural enemies to achieve the broadest pest suppression benefits. Land managers invest time, money, and land when implementing conservation biological control techniques. Returns on this investment are the reduction of expensive insecticide applications and environmental stewardship. Identifying native plants that harbor natural enemies in multiple habitat strata through out the year, rather than only when they are in bloom, will contribute to the science and practice of conservation biological control.

The goal of this research was to evaluate native species of perennial plants for their value in harboring assemblages of arthropod natural enemies. A comprehensive analysis of the natural enemy communities associated with these plant species will complement existing research and provide new insight into the value of native plants in conservation biological control. In contrast to previous research, we examined the foliar natural enemy communities associated with plant species when the plants were in bloom and when flowers were absent. Furthermore, we determined which plant species harbored the most epigeal (ground-dwelling) natural enemies. Specifically our objectives were to (1) determine which plant species harbor the greatest abundance of foliar-dwelling natural enemies overall and at different times of year; (2) compare the composition of foliar natural enemy assemblages between plant species; and (3) determine which plant species harbor the greatest abundance of ground-dwelling natural enemies.

Materials and Methods

We selected 10 native plant species (treatments) consisting of seven forbs and three grasses from four plant families for this study (Table 1). The plants are native to Maryland and much of the United States (see USDA–NRCS 2008 for range information). Forty 1.5 by 1.5-m plots were arranged in a 4 by 10-plot rectangular grid with one plant species (treatment) per plot in four replicates. Plots were separated by a tall fescue, *Festuca arundinacea* Schreber (Poaceae), 3-m-wide buffer that was mowed regularly to prevent any potential weeds from flowering. The experimental site was bordered by tall fescue on all sides. Treatments were arranged in a randomized complete block de-

Table 1. Native plant species used in research

Common name	Scientific name	Family
Common milkweed	*Asclepias syriaca* L.	Asclepiadaceae
Butterfly weed	*Asclepias tuberosa* L.	Asclepiadaceae
Threadleaf coreopsis	*Coreopsis verticillata* L.	Asteraceae
Hyssopleaf thoroughwort	*Eupatorium hyssopifolium* L.	Asteraceae
Spotted horsemint	*Monarda punctata* L.	Lamiaceae
Mountain mint	*Pycnanthemum tenuifolium* Schrader	Lamiaceae
Skullcap	*Scutellaria integrifolia* L.	Lamiaceae
Switchgrass	*Panicum virgatum* L.	Poaceae
Indiangrass	*Sorghastrum nutans* L.	Poaceae
Little bluestem	*Schizachyrium scoparium* Michaux	Poaceae

sign, where each plant species was randomly assigned to one plot in each row. One-year-old potted plants, of local genotypes, were established in June 2002, and arthropod sampling began in June 2003 and continued into 2004.

Foliar-Dwelling Arthropod Community. Data on arthropod taxa and abundance were collected by beat sampling foliar parts of each plant with a funnel sampling apparatus designed for this purpose. The funnel sampling apparatus consisted of a 1-pint mason jar containing 70% ethanol that was attached to the bottom of a metal funnel that was 30 cm in diameter. A plastic and mesh sieve, which fit on top of the funnel, was used to beat plant material so arthropods were dislodged and fell down the funnel into the jar. This apparatus helped to standardize the method and volume of plant material sampled in each plot. On each sampling date, two areas of the foliage and flowers in each plot were selected at random and beat six times into a single sample jar (=1 sample for each plot on each date). Samples of the foliar plant parts were taken on 17 June, 11 July, and 8 September 2003 and 8 June, 22 June, 16 July, 28 July, and 9 August 2004. Natural enemies in each sample were identified to order for spiders (Arachnida) or order and family for insects (Insecta) and trophic guild (predator or parasitoid).

Ground-Dwelling Arthropod Community. Data on arthropod taxa and abundance were collected using pitfall traps. Two traps were installed near the center of each plot by inserting glass vials (18 mm diameter) filled with propylene glycol into the ground with the opening just below the soil surface. Contents of the two traps were combined to make a single sample from each plot on each date. Traps were placed in the plots for 1 wk beginning on 23 June and 1 September in 2003 and on 3 June and 16 July in 2004. Natural enemies in each sample were identified to order for spiders or order and family for insects, and trophic guild (predator or parasitoid).

Statistical Analysis. To determine which plant species harbored the most foliar natural enemies overall, all sampling dates were pooled within each year. From this pooled data set, four categories of natural enemies were analyzed: total natural enemies (all predators and parasitoids combined), spiders, insect predators, and parasitoids. Data for each category were analyzed by analysis of variance (ANOVA) followed by Fisher protected least significant difference (LSD) means separation to identify differences between plant species (SAS Institute 2002). Years were analyzed separately because the number and timing of sampling dates was different between years. All data were log(x + 1) transformed before analysis to correct for non-normal distribution.

To determine which plant species harbored the most foliar natural enemies at different times of year, natural enemy abundance was analyzed on each sampling date within each year. For these analyses, natural enemies were broken into two categories: total predators (spiders and insect predators combined) and parasitoids. A separate ANOVA was conducted for predators and parasitoids on each sampling date followed by Fisher protected LSD means separation to identify differences between plant species (SAS Institute 2002). All data were log(x + 1) transformed before analysis to correct for non-normal distribution.

Many foliar natural enemy taxa did not occur in sufficient numbers to compare their abundance using parametric analysis. Therefore, χ^2 tests were used to determine whether the composition of natural enemy communities was independent of plant species. Natural enemies were divided into five groups, spiders, coleopteran predators, hemipteran predators, miscellaneous predators, and parasitoids, which represent the most abundant natural enemy taxa captured. The frequency of individuals in these five groups on each plant species (sum of all sample dates) was analyzed for each year by a χ^2 test.

To determine which plant species harbored the most epigeal natural enemies, sampling dates within each year were pooled because of the small values of many taxa. From these pooled data, two primary groups of natural enemies were analyzed: predators (spiders, staphylinids, and carabids combined) and parasitoids. We also performed a separate analysis for spiders, staphylinids, and carabids because these groups are of general interest in conservation biological control research. To determine differences in abundance of each group collected per sample, each natural enemy category was analyzed by ANOVA with year as a blocking factor (SAS Institute 2002). ANOVA was followed by Fisher protected LSD means comparisons (SAS Institute 2002).

Results

Foliar-Dwelling Arthropod Community. Plant species had a significant effect on the year-long abundance of total natural enemies ($F_{9,30} = 23.22, P < 0.001$; $F_{9,30} = 23.42, P < 0.001$), spiders ($F_{9,30} = 18.27, P < 0.001$; $F_{9,30} = 24.36, P < 0.001$), insect predators ($F_{9,30} = 10.69, P < 0.001$; $F_{9,30} = 11.47, P < 0.001$), and parasitoids ($F_{9,30} = 8.19, P < 0.001$; $F_{9,30} = 10.74, P < 0.001$) captured in 2003 and 2004, respectively. Mean comparisons showed significant differences in overall abundance for each natural enemy group

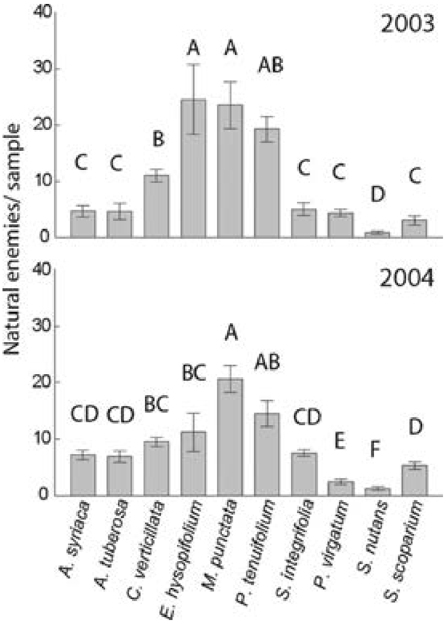

Fig. 1. Average number of natural enemies (all predators and parasitoids combined) captured in the foliar parts of each of 10 native plant species in 2003 and 2004. Bars with different letters within a year are significantly different ($P < 0.05$) by MEAN comparisons.

examined between plant species within each year (Figs. 1–4).

The effect of plant species on predator abundance was significant on all dates in both years (Table 2). Patterns of abundance between years were very similar; therefore, only 2004 data are presented in the figures. For example, in the 11 and 16 July samples from 2003 and 2004, respectively, *P. tenuifolium* had the greatest abundance of predators and parasitoids. Significant differences in abundance were found between plant species on each date (Fig. 5). Parasitoid abundance was significantly different on the latter three dates in 2004 (Table 2). There were significant differences in parasitoid abundance between plant species on each date that plant effect was significant (Fig. 6).

Composition of the foliar natural enemy assemblages differed between plant species in each year. Frequencies for miscellaneous natural enemies were not analyzed because counts were too low (values < 5) for χ^2 tests. However, the miscellaneous category is presented in figures to show the contribution of these predators to the community. The natural enemy assemblage on each plant species was comprised of different frequencies of the four natural enemy groups in 2003 ($\chi^2_{27} = 166.0, P < 0.001$) and 2004 ($\chi^2_{27} = 235.3, P < 0.001$; Fig. 7).

Ground-Dwelling Arthropod Community. Plant species had a significant effect on the abundance of total predators ($F_{9,69} = 2.44, P = 0.018$) and parasitoids ($F_{9,69} = 3.99, P < 0.001$). Mean comparisons within predators and parasitoids determined several significant differences among plant species (Fig. 8). Plant species also had a significant effect on staphylinid

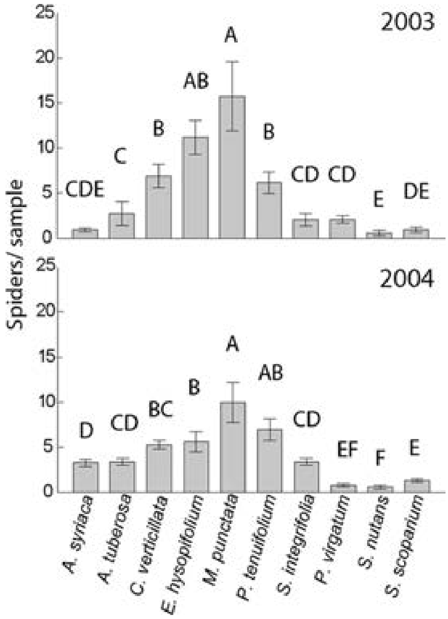

Fig. 2. Average number of spiders captured on the foliar parts of each of 10 native plant species in 2003 and 2004. Bars with different letters within a year are significantly different ($P < 0.05$) by LSD comparisons.

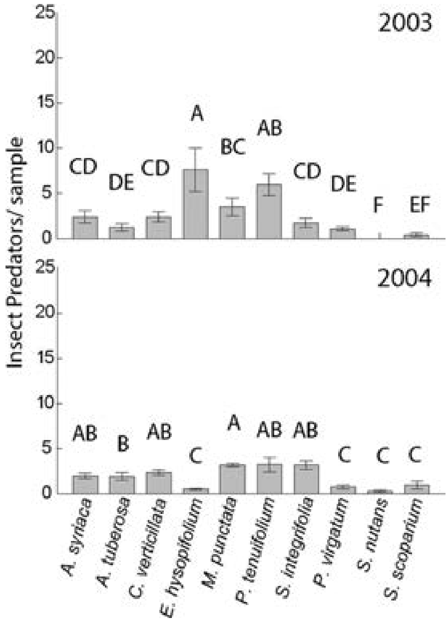

Fig. 3. Average number of insect predators captured in the foliar parts of each of 10 native plant species in 2003 and 2004. Bars with different letters within a year are significantly different ($P < 0.05$) by LSD comparisons.

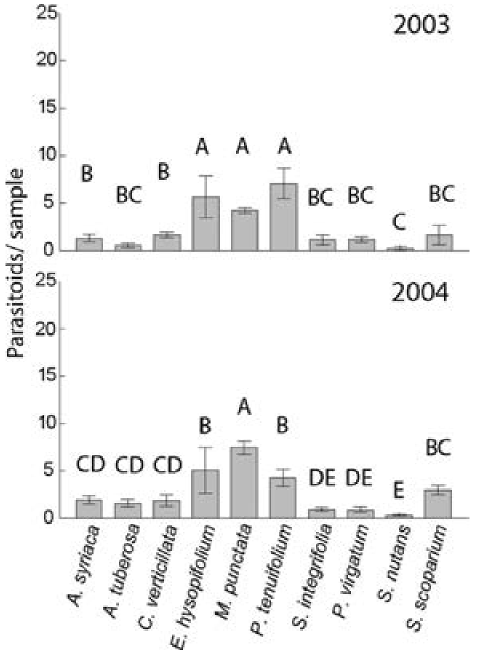

Fig. 4. Average number of parasitoids captured in the foliar parts of each of 10 native plant species in 2003 and 2004. Bars with different letters within a year are significantly different ($P < 0.05$) by LSD comparisons.

abundance ($F_{9,69} = 2.03$, $P = 0.049$) and a marginally significant on spider abundance ($F_{9,69} = 1.94$, $P = 0.061$). Staphylinids were most abundant in *A. syriaca, A. tuberosa,* and *S. integrifolia* plots. Spiders were also most abundant in *A. syriaca* and *A. tuberosa* plots. Plant species did not have a significant effect on carabid abundance ($F_{9,69} = 0.58$, $P = 0.812$).

Discussion

Our goal was to identify plant species native to Maryland and much of the United States with the potential to benefit conservation biological control by harboring natural enemy communities. Eight of the 10

Table 2. Results of ANOVA for the effect of plant species on total predators and parasitoid wasps in foliar plant parts on each sampling date in 2003 and 2004

	Predators		Parasitoids	
	$F_{9,30}$	P	$F_{9,30}$	P
2003				
June 17	3.03	0.012	1.18	0.348
July 11[a]	9.50	<0.001	4.23	0.001
Sept. 8	16.98	<0.001	5.78	<0.001
2004				
June 8	3.4	0.006	1.12	0.377
June 22	6.5	<0.001	1.85	0.100
July 16	11.01	<0.001	3.8	0.003
July 28	5.96	<0.001	5.27	<0.001
Aug. 9	9.14	<0.001	5.57	<0.001

[a] Degrees of freedom 9,29 because of a missing value for *E. hyssopifolium.*

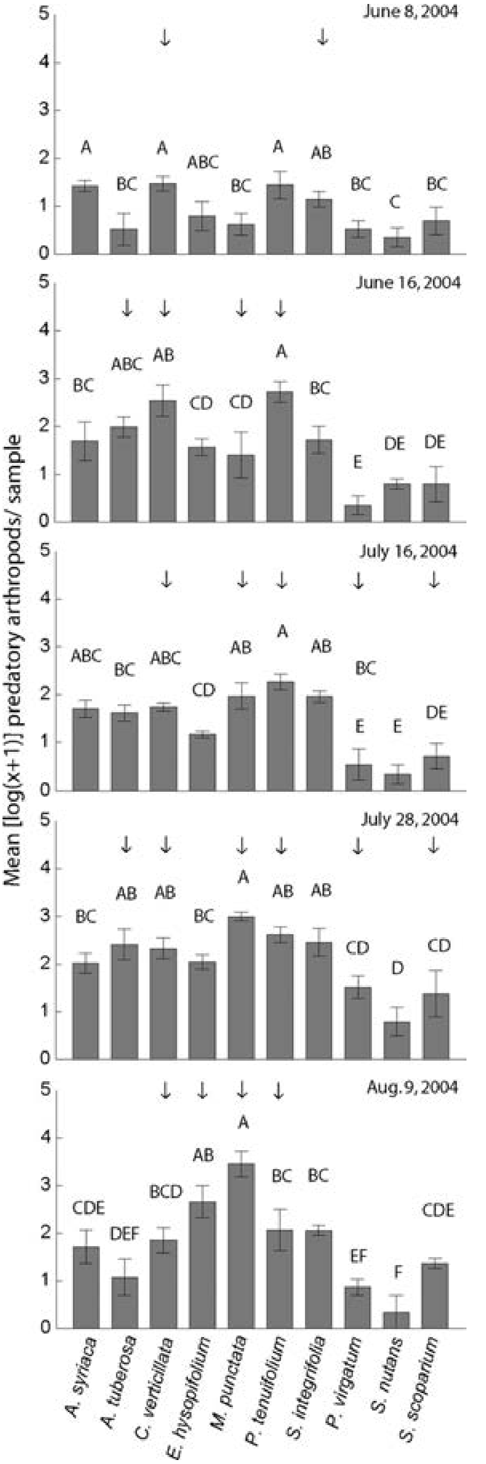

Fig. 5. Average number of predators (spiders and insects combined) captured in the foliar parts of each of 10 native plant species on 8 June, 22 June, 16 July, 28 July, and 9 August 2004. Bars with different letters within a date are significantly different ($P < 0.05$) by LSD comparisons. Arrows indicate that at least 40% of the plants or stems in a plot were flowering.

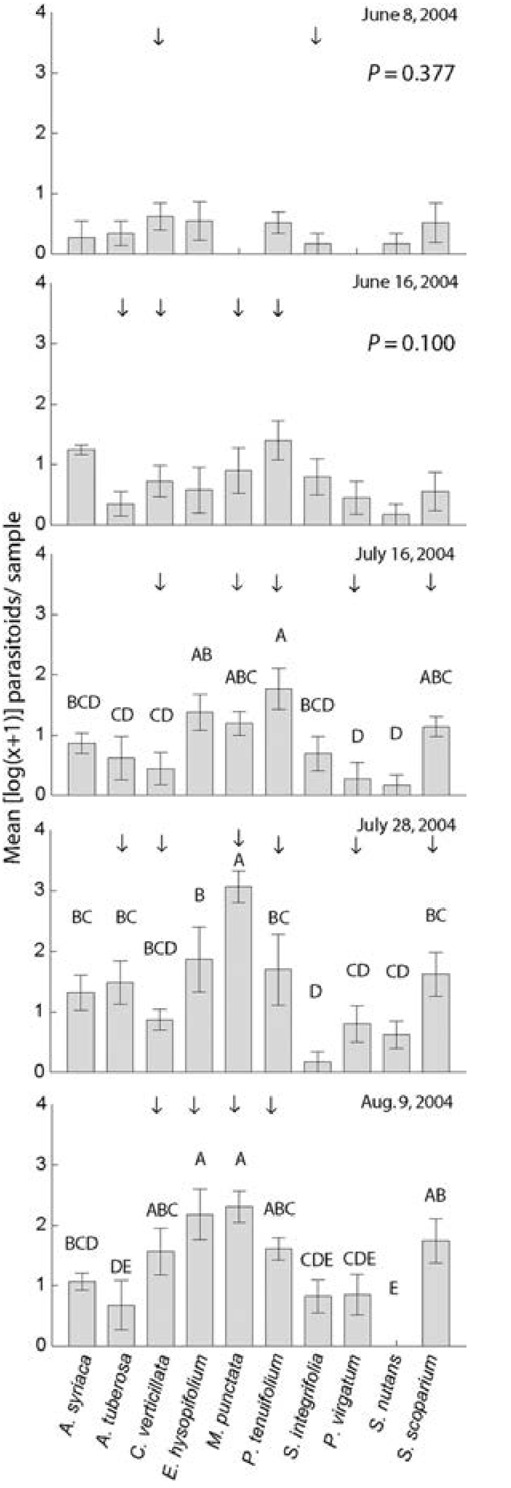

Fig. 6. Average number of parasitoids captured on foliar plant parts on each of 10 native plant species on 8 June, 22 June, 16 July, 28 July, and 9 August 2004. Bars with different letters within a date are significantly different ($P < 0.05$) by LSD comparisons. Arrows indicate that at least 40% of the plants or stems in a plot were flowering.

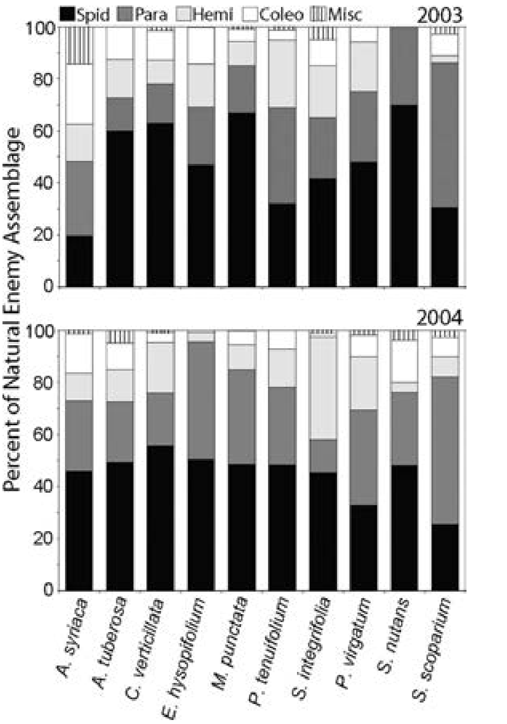

Fig. 7. Percentage of foliar-dwelling natural enemies that were spiders (Spid), parasitoids (Para), Heteropteran predators (Hemi; primarily *Geocoris* spp. (Lygaeidae), *Orius* spp. (Anthocoride), predatory stinkbugs (Pentatomidae), Coleopteran predators (Coleo; primarily coccinellidae), miscellaneous predators (Misc; primarily green lacewing larvae [Neuroptera: Chrysopidae]), syrphid fly larvae and adults (Diptera: Syrphidae), and earwigs (Dermatpera: Forficulidae) in natural enemy assemblages on each of 10 native plant species in 2003 and 2004.

plant species investigated in this study have never been evaluated for their attractiveness to arthropod natural enemies. Overall, plant species performed consistently between 2003 and 2004, although the abundance and composition of the natural enemy community varied throughout the year and between the foliar and ground habitat strata. Our study of these plant species provides new information to researchers developing habitat manipulation techniques and highlights the importance of studying the spatial and temporal composition of natural enemy communities.

Plant species in this study harbored different abundances of foliar-dwelling natural enemies. In addition, the assemblage of natural enemies present on each plant species was composed of different percentages of each predator or parasitoid group. The abundance of all four natural enemy groups among plant species was remarkably similar between years. This finding is important because growers will require that plant species provide consistent benefits each year these perennial plants remain in the landscape. As such, *M. punctata*, *P. tenuifolium*, and *E. hyssopifolium* harbored the greatest total abundance of predators and parasitoids in 2003 and 2004. Particularly in 2003, the abun-

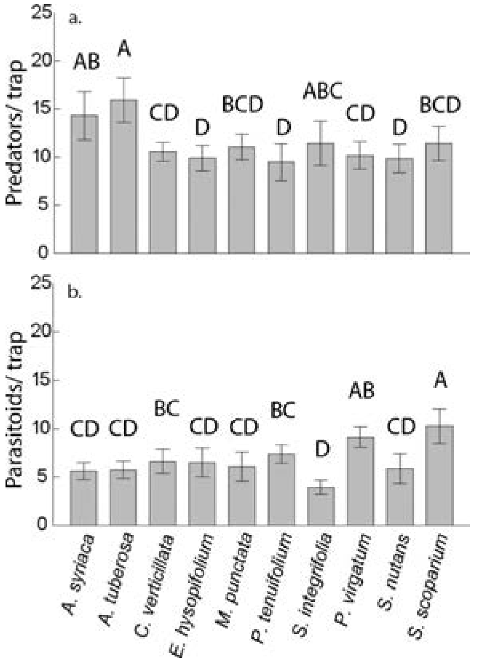

Fig. 8. Average number of epigeal predators (spiders, carabids, and staphylinids combined) and parasitoids captured by pitfall traps in each of 10 native plant species. Bars with different letters within taxa are significantly different ($P < 0.05$) by LSD comparisons.

dance of natural enemies captured on these three species was largely driven by a high abundance late in the season when plants were in bloom. Similarly, Fiedler and Landis (2007) found *M. punctata* attracted a large number of natural enemies during peak bloom compared with other native and exotic flower species. However, early in the season, *A. syriaca* and *C. verticillata* harbored as many predators and parasitoids as the three overall top performers. In contrast, the highest abundance of natural enemies captured on some species such as *A. syriaca* and *S. integrefolia* did not correspond with the bloom times of those species. These results indicate that some plant species can provide season long benefit by attracting natural enemies even if they are not blooming and underscores the need to sample plant species throughout the growing season.

Assemblages of foliar natural enemies on plant species were comprised of different proportions of spiders, parasitoids, and coleopteran, heteropteran, and miscellaneous insect predators. This is an important finding because each of these natural enemy groups likely provide biological control for different suites of pests. Therefore, even plant species that attracted fewer natural enemies may be attractive to a species of natural enemy that feeds on a particular pest. Heteropteran predators such as bigeyed bugs, *Geocoris* spp. (Lygaeidae), minute pirate bugs, *Orius* spp. (Anthocoridae), and predatory stink bugs (Pentatomidae) made up a small percentage of the predators present on most plant species. However, these versatile predators can play an important role in biological control by consuming aphids, eggs and larvae of lepidopteran pests, and other small arthropods (Chaney 1998, Eubanks and Denno 2000, Landis et al. 2000). The assemblage associated with *A. syriaca* has fairly even percentages of the four most common natural enemy guilds but a consistently large percentage of coleopteran predators compared with other plant species. Coleopteran predators in this study were primarily coccinellid beetles. Coccinellids have been conserved in many cropping systems by habitat manipulation and have been shown to reduce the abundance of aphids and other pests (Patt et al. 1997, Obrycki and Kring 1998). Plant species such as *E. hyssopifolium, M. punctata,* and *P. tenuifolium,* which had the greatest abundance of natural enemies overall, have assemblages dominated by spiders and parasitoids. Habitat manipulation techniques have routinely shown success attracting spiders (Riechert and Bishop 1990) and parasitoids (Chaney 1998, Stephens et al. 1998, Tylianakis et al. 2004), often with concomitant reductions in pest abundance. Identifying differences in the composition of natural enemy communities, even at a coarse level, improves the ability to select plant species with a natural enemy assemblage that complements a particular pest complex.

Habitat refuges such as beetle banks (Thomas et al. 1991), conservation strips (Frank and Shrewsbury 2004), and hedgerows (Dennis and Fry 1992) have long been studied as a way to increase the abundance of ground-dwelling natural enemies in agricultural and ornamental systems. The plants we tested harbored different abundances of predators and parasitoids. The most parasitoids were captured in pitfall traps within grasses, which had depauperate foliar-dwelling parasitoid communities. Parasitoids captured in pitfall traps may represent individuals residing in the lower parts of the foliage or on the ground. In either case, the relative abundance of parasitoids between plants is different in pitfall traps than in beat sampling. This suggests that pitfall traps sampled a pool of parasitoids that would be unobserved in research that only sampled upper plant foliage and flowers.

Predators, particularly ground-dwelling spiders, were captured in similar numbers among most plant species but were most abundant in the two *Asclepias* species. Interestingly, grasses, which are most commonly used in beetle banks, did not harbor the greatest abundance of predators. Frank (2003) found similar results in research that combined a bunch-type grass and flowering plants into conservation strips to attract both epigeal and foliar natural enemies to golf course fairways. Pitfall trapping within the conservation strips found a greater abundance of epigeal predators in alyssum and coreopsis flowers than in switchgrass. It seems forbs offer structural diversity and increased floral resources, which benefits natural enemies and their alternative prey (Landis et al. 2000). Thus, habitat manipulations intended to bolster epigeal predator populations would benefit from having flowers intermixed with the bunchgrasses traditionally used in beetle banks.

The abundance of carabid beetles and spiders did not differ between plant species. Therefore, the presence of plant material in general may be more beneficial for these predators than any particular plant species because they are not feeding directly on floral resources. In this way, any type of vegetation complexity added to agro-ecosystems will likely increase the abundance of ground-dwelling predators (Frank and Shrewsbury 2004). A further benefit of the perennial plant species used in our study is that they provide overwintering habitat in the form of standing dry plant material, thatch, and leaf litter. These aspects of habitat complexity are important for survival of carabids and other ground dwelling predators near agricultural fields (Thomas et al. 1991, Landis et al. 2000). Providing overwintering habitat allows predators to remain in fields rather than immigrate to field edges and may lead to a more consistent predator population over time (Thomas et al. 1991). Perennial plants also do not need to be replanted each year, which may reduce the cost to growers of maintaining habitat for natural enemies. For these reasons, more research should be conducted using perennial rather than annual plant species.

Exotic plant species are colonizing natural and managed landscapes to the detriment of native plant species and communities (Vitousek et al. 1997, Pimentel et al. 2000). The loss of native plant diversity has consequences for plant species preservation but also for native arthropods and other fauna that rely on food and habitat resources those plants provide (Samways et al. 1996). Agricultural intensification and the spread of urban areas reduces habitat for native plants, invertebrates, and vertebrates (Hole et al. 2005). The loss of native plants and their associated arthropods may deprive humans of valuable ecosystem services such as pollination and biological control and increase costs associated with land management (DiTomaso 2000, Gurr et al. 2003, Tscharntke et al. 2005). However, properly managed farm and urban landscapes can provide important habitat and resources for these threatened groups (Robinson and Sutherland 2002, Benton et al. 2003, Hole et al. 2005). As pressure on native habitats increases, managed areas have the potential to make a significant contribution to the preservation of native plant and animal species (Freemark et al. 2002).

Our research showed that native plant species such as *M. punctata, P. tenuifolium,* and *E. hyssopifolium* can harbor an abundance of foliar- and flower-dwelling natural enemies and that forbes can harbor as many or more epigeal natural enemies as grasses. However, in these plant species as in other systems, the natural enemy community differs dramatically between the ground and foliar habitat strata (Frank et al. 2007). Hence, a combination of flower and grass species may be most successful at harboring an abundance of natural enemies from multiple guilds that attack pests on the ground and in the foliage of pest prone plants. Identifying plant species that attract natural enemies in general, at different times of the year, and taxa important to biological control is the first step in developing new habitat manipulation protocols. Future research should establish promising native plant species from this study in pest-prone, managed systems to evaluate their value in reducing in situ pest populations and reducing plant damage.

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